UNIVERSITY OF GOTHENBURG
SCHOOL OF BUSINESS, ECONOMICS AND LAW

Moving Beyond the Small Talk

The impact of mobile phones on economic performance in Sub-Saharan Africa

Authors:
Anna Pernevall
Anton Ståhl

Bachelor thesis in Economics, 15 credits
Department of Economics
Spring Term 2015
Supervisor: Per-Åke Andersson

Abstract

This thesis is an addition to the growing body of economic research centred on the rapid diffusion of mobile phones in the developing world. The aim is to isolate and quantify the economic impact in terms of GDP per capita growth that is associated with the presence of mobile phones in Sub-Saharan Africa. A dataset containing panel data for the countries in the region is created and used to estimate a fixed effects model, endogenising their average annual growth rates. A positive impact is found and calculated to about 0.2 percent of annual growth for an increase of 10 mobile phones per 100 people. In the final section, this result is analysed in terms of elements which are potentially overestimated or underestimated with respect to reality. Some areas of general uncertainty surrounding the results are also highlighted and discussed. Lastly, policy implications derived from the analysis are presented.

Acknowledgment

We would want to thank our supervisor Per-Åke Andersson who helped us along the way in the process of creating this bachelor thesis.

Table of Contents

1. Introduction

While a rapid spread of mobile phones is an observable phenomenon in large parts of the developing world, it is arguably in the African context that it has the most potential for transformative impact. The overall level of infrastructure in Sub-Saharan Africa is low by global standards so the substitutive role of the mobile phone could be especially large in this region. Moreover, the continent has also so far largely lost out on the wave of fast growth that has brought large parts of Asia firmly into middle income territory. Large potential for rapid growth in combination with an unprecedented spread of mobile phones thus make Sub-Saharan Africa a highly interesting region for a study of the link between the two.

This thesis will examine this relationship; more specifically it is going to investigate the effect of mobile phones on economic growth in GDP per capita. The impact will be estimated empirically using regression analysis and panel data for the countries in the region. The methodology draws on earlier studies while it has been modified to suit the nature of the data. Econometric impact studies have been carried out before but none after the arrival, and rapid diffusion of, the various mobile based services discussed in the literature section. Nor have they used panel data focusing specifically on the region of Sub-Saharan Africa, which may have resulted in the omission of important explanatory variables. These circumstances have shaped the scope and direction of this thesis and represent the void it aims to fill.

The aim of this thesis is to answer the following question:

How does the prevalence of mobile phones impact the growth in GDP per capita in Sub-Saharan Africa?

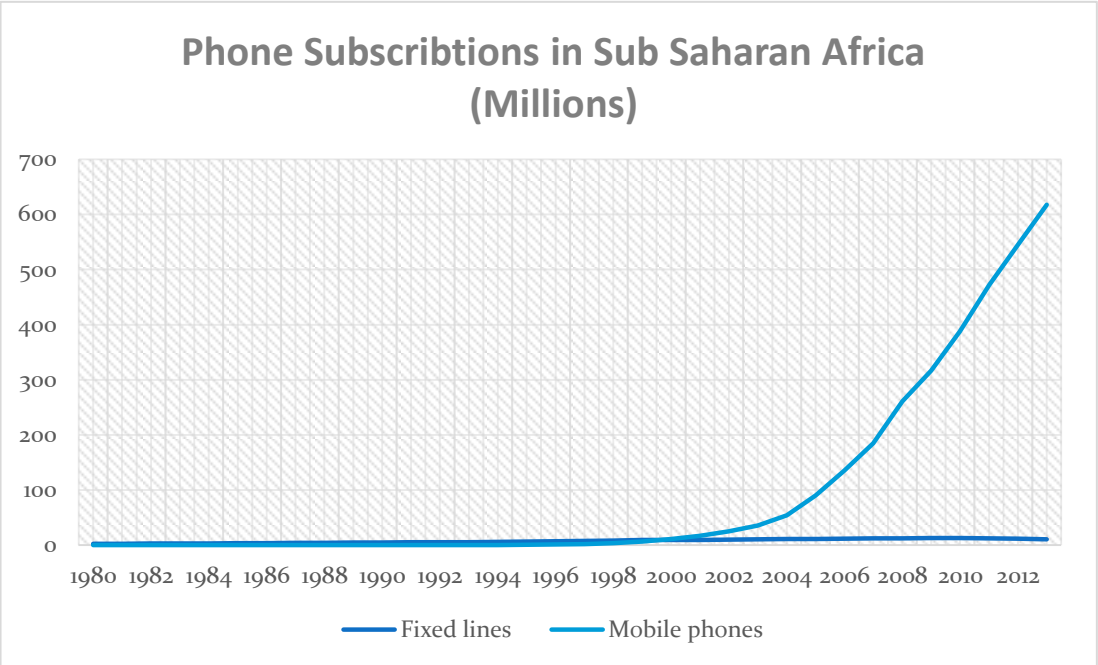
This thesis tests the hypothesis that mobile phone penetration has a positive impact on growth in real GDP per capita.

2. Literature review

This section contains a brief overview of the previous literature relating to the research question at hand. It aims to put this thesis into its academic context and convey the actuality and importance of studies on this rapidly expanding topic of research.

In the developed world, smartphones – handsets with internet connectivity - are to an increasing extent replacing ordinary mobile phones and the fixed line phones that came before them. In other parts of the world, however, ordinary mobile phones are making their way into the hands of more and more people. Sub Saharan Africa is a prime example of this. Even though smartphones and internet connections are still quite rare, mobiles are spreading rapidly, albeit somewhat unevenly, across the region. Moreover, the adoption rate of mobile phones is the fastest of any major technology to date (Jack & Suri 2011). In only a few decades, the number of subscriptions has gone from a few millions, on par with the fixed lines, to over 600 million (ITU 2015).

Graph 1.



Source: ITU World telecommunication/ITC indicators database

Africa has largely leapfrogged the land lines that preceded the mobile phones in the developed world. This is because while the roll-out of an extensive fixed-line network has been prohibitively expensive, especially in sparsely populated areas with a low level of

overall infrastructure, a mobile network is relatively cheap. Signal towers can provide coverage to large swathes of surrounding area all the while the price of the handsets themselves has dropped continuously. The scale and speed with which mobile phones have penetrated the continent makes it a major story and one that has warranted the attention of those interested in the future of Africa (Aker 2010).

Some studies have tried to explain what factors drive the adoption of mobile phones, both in the context of the developing world in general as well as in Sub-Saharan Africa in particular. Determinants range from those relating to geography and income (Baliamoune-Lutz 2003) to industry structure and regulatory framework (Curwen & Whalley 2005) to demographic factors and the gap between urban and rural adoption rates (Shanmugavelan & Wariock 2004). Sidhar and Sidhar (2007) point out the increased competition in telecommunications sectors around the world as responsible for increased investments in related infrastructure and a sharp drop in usage prices.

Others have tried to evaluate the impact on the societies where it is so rapidly being introduced, as the economic impact of mobile phones can potentially go far beyond that of the fixed line phones. This is because mobile phones represents the first effective, cheap and reliable medium of communication in many places and in addition bring a host of other kinds of benefits. Aker and Mbiti (2010) sum up the five channels of potential economic benefit associated with mobile phone proliferation. The first one is related to the assumption of perfect information and the way in which mobile phones can serve to strengthen the validity of that assumption. Access to a mobile phone for people and firms in less developed regions means a dramatically lower barrier to obtaining and spreading information. The time and money that has to be spent obtaining information for example about prices in different markets is substantially lower with a phone than by personal travel, which is often the alternative. Evidence to support the existence of such an effect has been uncovered on the micro level. Mobile access was found to improve the situation for both consumers and producers when studied among fishermen in Kerala (Jensen 2007) and among grain farmers in Niger (Aker 2008). The second channel of impact is through improved supply chain management among firms. This is the effect cited in an early study of the economic benefits of investment in telecommunication (Hardy 1980) where a positive linkage was found. The third way for mobile phones to have an economic impact is directly through the ecosystem of employment that accompanies the roll-out of an extensive mobile phone network. New jobs have been created to charge, repair and sell phones as well supply users with ways to top up

their accounts with new air-time. The fourth channel covered by Aker is the role that mobile phones can serve in mitigating risk in society. Mobile phone usage will reduce the costs, and increase the speed, of communication inside the family networks that provide the primary social safety net in most African societies. This in turn would make it easier for them to respond to unexpected economic shocks.

Lastly, the mobile phones play an important economic role as platforms for the delivery of various kinds of services. The "M-services", as they have come to be known, span across several sectors. These range from health (Granot et al. 2008) to education (Aker 2009) and agricultural advice (Aker 2011). Increasing the yields in the agricultural sector could have a major economic impact as two thirds of people in the region are still employed in agriculture and the sector makes up a third of regional GDP (World Bank 2009). The Gates foundation (2015) sees the mobile phone as playing a major role in all of the areas mentioned above, as stated in their list of expected breakthroughs in the fight against poverty. Included in that list is also the M-service that has gotten the most attention of them all, Mobile Money.

Mobile money is an umbrella term that includes services that only facilitate transactions of cash as well as more sophisticated versions that include connection to a bank account. M-money services in both of these forms are especially prevalent in Sub-Saharan Africa. The release of the 2014 Global Findex report on financial inclusion by the World Bank showed that 700 million people have been brought into the formal financial system since the last report was released in 2011. A large part of this increase, especially in Sub-Saharan Africa, can be accredited to the people who have gained financial access through a mobile banking account. Full financial inclusion by 2020 is an aim that the World Bank sees as a vital step towards its overreaching goal of ending extreme poverty by 2030. Access to financial services is important in this regard for two reasons. Both because it gives a direct positive effect for the individual by giving them access to safer savings and credit to better manage risk (Mbiti & Weil 2011), but also because financial access plays an important intermediary role in areas such as health, education and agriculture. For example Brune and Giné (2014) found that access to a bank account increased the output among Malawian farmers as they increased their savings, and subsequent investments, when accounts became available to them.

All of this micro level evidence of a connection between mobile phones and economic performance has led some researchers to look for traces of this link in the macroeconomic data. In a 2001 study, Röller and Waverman investigates the connection between

telecommunications infrastructure and economic growth in a sample of OECD countries and finds a substantial impact to exist. They find that 10 percentage points of additional mobile phone penetration increases the growth rate by 1.5 percentage points. Waverman (2005) extends the analysis to developing countries and finds an impact there as well, albeit of a smaller magnitude; the same change in penetration correlates with 0.6 points of growth according to his estimates. Aker and Mbiti (2010) raise some points regarding these analyses however, in particular the way it dealt econometrically with potential two-way-causality problems. Waverman uses lagged land line penetration as an instrument variable but Aker and Mbiti (2010) note that this is theoretically unsound as the lack of an extensive land line network often serves as a driver for the adoption of mobile phones rather than the other way around.

While most researchers have shed light on the positive impact of the mobile phones there have also been some highlighting the potentially adverse effects. From an economic standpoint there is some evidence pointing to how mobile phones can decrease trade between countries and ethnic groups (Aker, Klein, & O'Connell 2014). The social impact might not be one-sidedly positive either. By widening the social circle of the user, mobile phones could challenge and eventually break up long standing social structures with unpredictable consequences (Aker & Mbiti 2010).

3. Theoretical framework

Two major sources serve as the theoretical underpinning for the model tested in this thesis. The first one is a paper by Robert Barro (1991), written as he pioneered the field of growth econometrics using the first comprehensive dataset available on cross country growth. It isolates a few fundamental growth determinants using a sample of countries from all over the world. The second source is used as a complement as it concentrates on explaining the region-specific growth determinants of Sub-Saharan Africa, the region on which the attention of this thesis is focused.

In order to test the assumption that the proliferation of mobile phones has an impact on real GDP per capita growth in the long run, other factors that could also impact this metric need to be identified and controlled for. Isolating the determinants of long run growth is a central issue in the field of economics as small differences in the growth trend lead to large differences in outcomes when accumulated over long periods of time. The theoretical point of departure for this thesis is the econometric application of the Endogenous Technological Change model developed by Barro (1991) and used by Waverman (2005).

Barro uses a sample of countries from all around the world to uncover what factors can be econometrically proven to drive long run growth, starting with the convergence hypothesis derived from the Solow growth model. This predicts that countries that are initially relatively poor should experience faster growth, all else equal, due to the assumption of decreasing returns to GDP with respect to capital. The countries and regions with lower capital per worker ratios should attract investors who want to take advantage of the large marginal returns that the low capital intensity offers. The theory thus predicts a convergence towards the same levels of GDP per capita in countries with similar savings rates. The role of investment in short-term growth is found to have statistically significant explanatory value, as does the initial output per person of the country, but only in combination with other variables.

While the Solow model identifies technological progress in a very broad sense as the driver of growth in the long run, it does not specify what that means more specifically or what factors that determines it. To identify these other variables Barro draws on the theories of endogenous technological change that followed Solow. From this vast body of research he finds that the stock of human capital at the beginning of the period needs to be taken into account for the convergence hypothesis to appear. If a country has a relatively high stock of human capital in

relation to its initial per capita income, a catch up effect is supported by the data. He also tests two proxies for political stability and the prevalence and size of market distortions. A politically unstable situation has an adverse effect on economic growth as it serves to deter people from work and investment. This is because property rights often become less secure under such circumstances. Market distortions can take many forms but they all decrease the efficiency of the market and lead to a waste of resources in the economy. The last variable he finds to have some explanatory power is the amount of GDP that goes to government consumption. This is an aggregate measure and includes both productive and non-productive consumption, but on the macro level it has a negative influence on economic performance.

In a follow-up paper on the same topic from 2003, Barro makes use of newly released data to expand the concept of human capital to also include health capital. In the same paper he also finds that the economic openness of a country influences its economic performance in a positive direction.

What he also finds in his 1991 paper is that the Sub-Saharan Africa dummy that he adds to his regression is significant and explains 1-2 percentage points of annual per capita growth. He notes that this implies that region-specific growth determinants exist and are left out of the model but does not elaborate on what they might be. Out of the large body of research that has emerged to explain this shortfall, one of the most ambitious explanations is presented in The Political Economy of Economic Growth in Africa, 1960-2000 (Ndulu et al. 2008), published as a two volume series. It combines in-depth country level studies with cross country analysis to uncover the reasons behind why Sub-Saharan Africa as a region has grown relatively slow in the past, as well as explaining differences in economic performance between countries on the continent between 1960 and 2000.

> *"Where growth appeared to be dominated by factors poorly proxied in cross-country growth regressions, these factors were identified and evidence brought to bear on their importance." - (Ndulu et al. 2008, p. 11)*

Ndulu et al. (2008) uses an explanatory framework based upon opportunity and choice. By this the authors mean that the actual economic outcome can be understood as a combination of what opportunities that have been present and how policy choices determine if they get exploited or not.

They use measures of endowments and location to proxy for the amount of opportunities that the countries enjoy. As the existence of a dominant export commodity tend to exert a large influence on the overall economy, the first rough division is made into resource rich and resource poor countries. As a second stage the resource poor economies are divided into landlocked and coastal countries to cover the opportunity for international trade that oceanic access represents. Econometric evidence points to this as being reflective of growth opportunities in a global context (Ndulu et al. 2008, pp. 81 -86).

Choices represent the second part of the explanation according to the authors. This refers to policy and is represented by four distinct syndromes that the authors have identified and that serve to hamper economic growth. The syndromes are: regulatory, ethno-regional distributive, intertemporal and state breakdown. They have occurred to a different extent in different countries at different points in time, and only a few countries, such as Botswana and Mauritius, have been syndrome free for most of the period. The first one is closely linked to the periods of socialism that a lot of the countries had during the cold war. Since this is far less prevalent for the period covered by this thesis it is not taken into account. The ethno-regional syndrome refers to the presence of economically costly redistribution along ethno-regional lines that has been a common feature in many African countries. This is often connected to the process of elites securing their rule by channelling resources to rivals and supporters for political purposes. It is not to be confused with other kinds of economically warranted redistribution which was not found to have the same adverse effect on growth. The intertemporal syndrome refers to choices made that clearly overvalue the present over the future. That can mean either looting by the elite in anticipation of losing power or unsustainable spending which takes the form of unsustainable debt accumulation or that a country locks itself into patterns of irreversible spending. The last syndrome is state breakdown, a situation in which a country fails to keep the peace within its borders and perform its basic functions. Much like the political stability indicator that Barro found to be significant, this affects growth negatively by undermining the basic political institution that are a prerequisite for people to make long term economic commitments (Ndulu et al. 2008, pp. 89-96).

4. Data

This chapter will summarize and justify the data used in this thesis as well as elaborate on how it has been structured and applied in order to answer the research question.

A panel data set is used to empirically test the hypothesis that mobile phone penetration has a positive effect on economic growth in Sub-Saharan Africa for the period 1980-2013. This time frame is relevant because it encompasses periods before and during the rapid rise of mobile phone penetration in the region. It includes the newest data available, which captures the rapid development of M-services highlighted in the literature, but retains the long run perspective. A panel data set contains observations for the same cross section of countries at different points in time. In this thesis, the time-period is divided into six five year intervals (1980-2009) and one four year interval (2010-2013). The use of panel data is necessary as a simple cross section of the region's countries contains too few observations to produce statistically significant results. There are 48 countries in Sub-Saharan Africa and these are reduced to around 30 when taking into account the lack of data that plagues some of the variables. One year periods could have been used and would have provided even more observations but the drawback of this would be capturing the business cycles while the model aims to explain the growth trend. The choice of five year periods is thus a consequence of this trade-off, providing enough observations while still retaining a smoothing out effect on the cyclical variations.

By sorting the data as described above, the sample contains a total of 329 observations. A rule of thumb is to have at least 50 observations to be able to run a sensible simple regression and to increase the sample size for every additional independent variable. The lack of data in some of the variables makes the number of observations ranges from 224-329, which is sufficient to accurately estimate the model in this thesis.

The theory predicts the variables to affect GDP growth in two different ways, either by the stock in the beginning of each period or continuously during that period. To reflect this, the variables either take the form of the initial value or the average value of each interval.

Ideally the estimation would include all countries in the Sub-Saharan Africa region but since South Sudan did not exist before 2011, it is completely excluded from our analysis. Sudan in the data set therefore represents the united country up until 2011 and only present day Sudan

for the remaining years. Some other countries have missing data for one or more of the periods but none of them to the extent that they need to be excluded.

In order to test the validity of the hypothesis against reality, proximate measures of the real determinants of the dependent variable are found and used in the regression. The variables are chosen due to relevance for the analysis and the availability of data, which is sometimes a constraining factor in the context of Sub-Saharan Africa and the period of interest. The variables included have been chosen to control for other things that, in addition to our variable of interest, could have an effect on economic growth to avoid omitted variable bias in the results.

The variables initial GDP per capita, government expenditure, capital formation, life expectancy, years of schooling and merchandise trade are meant to proxy for the determinants isolated in the theory of Endogenous Technological Change model and verified by Barro (1991, 2003). The dummies for resource rich and coastal countries, political terror score and ethnic fractionalization are meant to proxy for the determinants from the theory presented in The Political Economy of Economic Growth in Africa 1960-2000 (Ndulu et al. 2008).

Theory predicts that the prevalence of market distortion has an impact on growth, however, as no variable with sufficient data for the period and region could be found it has been left out of the regression. The same applies to the intertemporal syndrome that the theory presents.

4.1 Variables

Below follows a short discussion of each of the variables used in the regression.

4.1.1 Main variables of interest

Dependent variable: real GDP per capita growth (annual %)

Real GDP per capita is widely used and provide the advantage of correlating closely with several other welfare indicators such as infant mortality and literacy rate, and can therefore be seen as a good proxy for quality of life in general.

There are potential negative aspects of using GDP per capita. A high population growth increases total GDP but may decrease GDP per capita, at least in the short run, because the dependency ratio of the population increases as the number of children grows. Having more children per working age adult means dividing the same total income on an increased total

population, thereby putting a downward pressure on GDP per capita. The use of real GDP per capita also represents a way of bypassing the inflation as it measures the real value of production which is independent of price changes. However, in the same way as with the population increase, this implicitly assumes that inflation does not affect the real level of output at all. These effects would ideally be accounted for in the model. Furthermore, GDP per capita is an average and therefore does not convey any information regarding the distribution of income within the population.

Independent variable: Mobile cellular penetration (per 100 people)

The variable mobile cellular penetration measures the number of mobile phone subscriptions per 100 people. The subscribers are measured as the total number of post-paid subscriptions and active prepaid accounts (ITU 2015). This may be problematic when used in the context of Sub-Saharan Africa, because the usage and ownership of the phone are distinctly separated in many of these countries. It is common to have access to a phone without owning it because family and friends share the phone or a person may own several phones but rent out some of them. It is the usage of the mobile phone and its services that give the big financial benefits, not if you own the phone or not (Aker & Mbiti 2010).

> *"…in spring 2013, when Pew Research asked Kenyans who did not own a cell phone whether they shared one with someone else, 58% of those non-cell phone owners said yes. And 21% of Kenyan mobile phone owners said that they shared their phones with others."* - *(Poushter et al. 2015).*

It is also common to have different SIM-cards but only one phone, as this makes it possible to use different networks to call different people, in order to maximise the free airtime that sometimes follow subscriptions. As a consequence of these practices, this variable may either underestimate or overestimate the mobile phone usage (Baliamoune-Lutz 2003). Even so, this is the best proxy for mobile phone usage that is available and assuming that the measurement errors are somewhat consistent across countries it will primarily affect the size of the estimator and not its statistical significance.

4.1.2 Variables controlled for

GDP per capita (constant 2005 US$)

This variable is used to cover for the convergence effect described in the theory section. With a lower GDP per capita in the beginning of the time period a country is assumed to be poor due to less capital per worker.

The logarithmic form is used here, as it commonly is for variables that take high nominal values, in this case US dollars (Wooldridge 2014, p. 157). In line with the convergence hypothesis, a rise in this variable is expected to have negative impact on growth in GDP per capita.

General government final consumption expenditure (% of GDP)

The behaviour of the government can affect the growth in GDP per capita in multiple ways and final consumption is one of them. This variable covers all consumption of goods and services as well as national defence and security but no other military expenditures. If the consumption increases its share of total GDP the per capita growth is expected to decrease.

Gross fixed capital formation (% of GDP)

This variable accounts for all domestic fixed capital investment in the economy, such as land improvements, roads, schools and hospitals. Theory predicts that capital investment should have a positive influence on the capital-to-labour ratio and thereby positively influence GDP growth.

Life expectancy at birth, total (years)

The number of years a new born child would live under current conditions, if they were to stay constant throughout the life of the child. This is an indication of the level of the general public health in the country and is therefore a proxy for human capital. It is determined by the mortality rate which means it do not measure for non-lethal diseases. This can be problematic since many non-lethal diseases can affect GDP per capita by causing people who suffer from them to not be able to work as efficient as healthy people. This variable is expected to have a positive effect on growth in GDP per capita.

Proxies for geographical opportunities

The geographical opportunities are proxied with dummy-variables for prevalence of natural resources and coastal access. These are divided into three categories pointed out as relevant in

the theory. The dummy for natural resources takes the value 1 if the country is resource rich and 0 if it is resource poor. The categorisation is based on the active exploitation of a dominant resource, not if this resource is present or not. The dummy for costal access take the value 1 if it is a coastal country and 0 if it is a landlocked country. The dummy for landlocked and resource poor countries is omitted and used as baseline dummy.

Political Terror Score

This is a proxy for the state breakdown syndrome and the political stability effect, as the two refer to the same growth inhibiting circumstances. It is measured on a scale from one to five.

1 is the best political situation and is described as:

> *"Countries under a secure rule of law, people are not imprisoned for their view, and torture is rare or exceptional. Political murders are extremely rare."*
> *- (Gibney et al. 2013)*

5 is the worst political situation and is described as:

> *"Terror has expanded to the whole population. The leaders of these societies place no limits on the means or thoroughness with which they pursue personal or ideological goals" – (Gibney et al. 2013)*

There are other measures of the political stability and quality of governance but none of them were available for the entire time period. This variable is deemed to be a good proxy as it covers the rule of law, highlighted as important in the theory. A higher terror score is expected to have negative effect on GDP growth.

Ethnic fractionalization

This variable is measured as the probability that two randomly selected people in a population have different ethnic backgrounds. In this context it serves as a proxy for the ethno-regional syndrome explained in the theory. An ethnically diverse population is not necessarily negative for growth in itself but in Sub-Saharan African countries it has often lead to this syndrome and is therefore expected to have a negative impact on growth.

The data for ethnic fractionalization is available for all of the years of interest but does not vary inside any of the periods. This has implications for the econometric regression, the reasons for this are presented in the methodology section.

Merchandise trade (% of GDP)

This variable is the sum of the merchandise export and import divided by the value of GDP in current U.S. dollar level. Trade has been shown to be a driver for growth and is therefore expected to have a positive effect on GDP per capita.

4.1.3 Additional independent variables

Average years of schooling

The average years of total schooling completed by the people over 15 years old is an important proxy for human capital. The stock of human capital is highlighted in the theory as an important growth determinant. However, there are several countries in our sample for which data for this variable is missing. Since the variable lacks observations the sample might no longer be assumed to be random. This is because countries for which that variable is lacking data are likely to do so because of similar reasons. Due to this it has been included in a separate regression to allow for comparison with the main regression.

Three year lagged capital formation

Investments are by definition forward looking and pay off with different time lags. It is therefore theoretically feasible to proxy the effect of capital formation with a lagged variable. We have chosen to include this variable in a separate regression so it is possible to compare with the main regression when it is excluded. It is constructed by shifting the five years average interval back three years in time for every period. The two variables are not used together in the same regression because they still share two years of investment data and will be highly correlated as a consequence.

4.2 Summary Statistics

Table 1

Summary Statistics

Variable	Number of Observation	Mean	Standard Deviation	Minimum	Maximum
country	329	24	13.59	1	47
time	329	1999.71	9.60	1985	2013
gdp_growth	316	1.27	5.17	-30.26	51.73
logGDP_initial	308	6.50	1.06	3.91	9.52
mobile_pen	329	14.12	27.59	0	161.59
gov_exp	299	15.97	7.63	2.80	50.94
cap_inv	301	21.73	15.58	2.53	179.98
years_school	224	4.04	2.02	0.62	9.69
life_expect	329	53.28	7.49	28.76	74.37
res_rich	329	0.30	0.46	0	1
coastal	329	0.40	0.49	0	1
pol_terror	326	2.76	0.95	1	5
ethnic_frac	282	0.72	0.20	0.18	0.95
trade	313	60.28	45.97	9.20	510.85
lag3_cap_inv	297	21.45	15.30	3.05	158.71

The mobile phone penetration variable ranges from 0 to 161 per 100 individuals for the periods and countries. The maximum value of 161 reflects the previously discussed phenomenon of multiple SIM-cards and the minimum of 0 mobile phones reflects the time period before the mobile entered the market. A relatively high standard deviation reflects the rapid spread of the mobile phones in the region.

There are some outliers in the sample, for example the minimum and maximum value in growth in GDP per capita. These reflect respectively unstable political situations in various countries and exploitation of oil in the small country of Equatorial Guinea in the 1990s. Government expenditures and capital formation also vary quite a lot from minimum to

maximum, as does trade. The minimum value of 9.20 represents the trade intensity for Swaziland in the time-interval 1985-1990. During these years the South African economy was severely affected by the sanctions imposed by the rest of the world on the apartheid regime. This also affected Swaziland's economy which is heavily dependent on South Africa because of its geographical location. The maximum value of 510.85 represents the trade for Madagascar in the interval 1995-2000. A relatively small domestic economy in combination with its geographic location making it a major transit point for maritime trade explains these seemingly extreme numbers. Coupled with the adoption of a new constitution promoting free trade boosted the export and import volumes during these years in particular (Utrikespolitiska Institutet 2015). When looking at the sample as a whole the data looks reasonable.

4.3 Sources and general data problems

The main source of data used in this thesis is The World Bank's database World Development Indicators (WDI), another major source was the database Standard Dataset from the Quality of Government institute. For some of the variables other sources were used, see details regarding data sources in Appendix I. These sources are widely used and are generally seen as trustworthy, however, there are always imperfections due to practical problems associated with gathering large amount of data. For example, the data for capital formation could be unreliable according to Barro (2003) because it depends on, among other things, judgements regarding the speed of depreciation and that entails some level of arbitrariness.

5. Methodology

To test panel data there are different methods available, in the following section the fixed effect model and the random effect model that were considered for this thesis are described. The Hausman test, used to decide which of the two is preferred, is also briefly explained.

5.1 Fixed effect model

This panel data method is used when each country is assumed to have individual time-constant characteristics that could impact the outcome, thus the fixed effect model allows controlling for these effects that are constant over time. This refers to those characteristics that are correlated with the countries error term (ε_{it}), which contains of one time-constant part (α_i) and one time-variant part (u_{it}). By using the fixed effect model it is possible to remove the time-constant effects so that the outcome is only affected by the time-variant variables.

$$\varepsilon_{it} = \alpha_i + u_{it}$$

For this reason it is only possible to include variables that are not-constant over time in this model (Wooldridge 2010, pp. 248-250, 265-268).

In the context of the model in this thesis the country time-constant characteristics are for example cultural, geographic or slowly changing demographic features that affect the average growth in GDP per capita. The three variables ethnic fractionalization, resource rich and coastal are example for these features. Since these effects are automatically accounted for in the fixed effect model they are excluded and seen as a part of the time-constant error-term.

5.2 Random effect model

This method assumes that the variations across countries are random and not correlated with the independent variables which allows the time-invariant part of the error term to be included. As the random effect model allows time-constant variation it is also possible to include independent variables that do not vary over time. That means the model includes both within-country and between-country effects. To be able to control for the country specific characteristics they need to be specified, which easily leads to omitted variable bias (Wooldridge 2010, pp. 257-261).

5.3 Hausman test

The Hausman test is used to test the null hypothesis that the fixed effect model and the random effect model are both consistent, in this case the random effect model is recommended since the assumption for that model is harder to obtain. The alternative hypothesis is that the random effect model is not consistent so the fixed effect model should be used.

The critical distinction between the fixed and random effect is the correlation with the error term, not if the variables are constant over time or not. The Hausman test shows the differences in the estimations between the two models and test if the error-term is correlated with the independent variables.

When tested in this thesis, the Hausman test calculates that the fixed effect model is the most suitable alternative for all the model-specifications tested. This means that the three time-constant variables originally included do not represent all of the country-specific time-constant characteristics. This is perhaps not that surprising, just as Barro (1991) found evidence of African specific growth determinants, there may very well be substantial differences between regions and countries within Africa. If that is the case, the fixed effect model is adequate as it automatically controls for the time-invariant country specific characteristics. (Wooldridge 2010, pp. 288-291)

The random effect model was run in addition to the fixed effect model in order to see how big the differences actually were and also to be able to include the three time-constant variables; resource rich, coastal and ethnic fractionalization, to see what impact they would have. The random effect model produced similar results. The output from the random effect estimation is presented in Appendix II.

5.4 Assumptions

To be able to run tests on panel data the assumptions from both time-series and cross-section data are considered in addition to the specific model assumption of the fixed effect model discussed above.

The most important assumption that need to be satisfied in order to get unbiased estimators is to have strict exogenity, which means that the time-variant error-term should be uncorrelated

with the independent variables for each time period. Omitted variables or reverse causality represent potential endogenity (Wooldridge 2014, p. 459). When testing growth in GDP per capita it is likely that some variable are omitted since growth in GDP per capita is affected by many factors and it is difficult to control for everything. We have included as many of the variables presented in the growth-theory as possible given the data available. Reversed causality has been discussed as a potentially problem in relation to this topic before (Aker & Mbiti 2010; Waverman 2005) and attempts have been made to control for this using an instrumental variable. But as it is difficult to find a variable that correlate with mobile phone penetration but not with growth in GDP per capita, it is beyond the scope of this thesis. However it is not clear that the reverse causality represents a major problem in the model using growth in GDP per capita as the dependent variable. The obvious connection between GDP per capita and mobile phone penetration lie in the absolute level of GDP per capita rather than in its growth rate. Strict exogeneity can therefore plausibly be assumed in this context (Wooldridge 2010, pp. 252-254).

Another important assumption is homoskedasticity, meaning that the variance of the error-term is constant across all independent variables. If this assumption is violated the standard errors will be biased which leads to incorrect estimations of the coefficients. The estimations will still be unbiased but inefficient and to control for this we used White's robust standard error. In the case of the regressions tested in this thesis, the robust standard errors differed only very slightly which implies that the homoscedasticity assumption holds.

No serial correlation entails that the error-term is not correlated with itself over time. When using fixed effect model we remove all time-constant effects, thereby reducing the risk of serial correlation. Correlation in the remaining time-variable part of the error-term is assumed not to be present.

The presence of multicollinarity between independent variables is assumed not to exist, which means the variables do not correlate strongly with each other. This would, if present, lead to an exaggerated estimation of the R-squared caused by the linear relationship in the variables and not by the explanation power of the model.

5.5 Model specification

The following are the four model specifications tested for

Model 1: Main regression excluding both lagged capital formation and years of schooling.

$$gdp\_growth_{it} = \beta_0 + \beta_1 logGDP\_initial_{it} + \beta_2 mobile\_pen_{it} + \beta_3 gov\_exp_{it} + \beta_4 cap\_inv_{it} + \beta_5 life\_expect_{it} + \beta_6 res\_rich_{it} + \beta_7 costal_{it} + \beta_8 pol\_terror_{it} + \beta_9 ethnic\_frac_{it} + \beta_{10} trade_{it} + \alpha_i + u_{it}$$

Model 2: Additional regression including years of schooling.

$$gdp\_growth_{it} = \beta_0 + \beta_1 logGDP\_initial_{it} + \beta_2 mobile\_pen_{it} + \beta_3 gov\_exp_{it} + \beta_4 cap\_inv_{it} + \beta_5 life\_expect_{it} + \beta_6 res\_rich_{it} + \beta_7 costal_{it} + \beta_8 pol\_terror_{it} + \beta_9 ethnic\_frac_{it} + \beta_{10} trade_{it} + \beta_{11} years\_school_{it} + \alpha_i + u_{it}$$

Model 3: Additional regression including lagged capital formation.

$$gdp\_growth_{it} = \beta_0 + \beta_1 logGDP\_initial_{it} + \beta_2 mobile\_pen_{it} + \beta_3 gov\_exp_{it} + \beta_4 lag3\_cap\_inv_{it} + \beta_5 life\_expect_{it} + \beta_6 res\_rich_{it} + \beta_7 costal_{it} + \beta_8 pol\_terror_{it} + \beta_9 ethnic\_frac_{it} + \beta_{10} trade_{it} + \alpha_i + u_{it}$$

Model 4: Additional model including both lagged capital formation and years of schooling.

$$gdp\_growth_{it} = \beta_0 + \beta_1 logGDP\_initial_{it} + \beta_2 mobile\_pen_{it} + \beta_3 gov\_exp_{it} + \beta_4 lag3\_cap\_inv_{it} + \beta_5 life\_expect_{it} + \beta_6 res\_rich_{it} + \beta_7 costal_{it} + \beta_8 pol\_terror_{it} + \beta_9 ethnic\_frac_{it} + \beta_{10} trade_{it} + \beta_{11} years\_school_{it} + \alpha_i + u_{it}$$

Model 1 is the main regression of interest where we exclude years of schooling and lagged capital formation since these variables can potentially have a misleading effect on the outcome. This means the only part of human capital controlled for is health and not the part of educational attainment. They are still interesting to test, however, since they are pointed out in the theory as important. They also serve the function of testing the robustness of the results obtained in the main regression to small changes in the specification.

6. Results

The following table shows the results from the four different regressions tested with the fixed effect model.

Table 2

	(1)	(2)	(3)	(4)
logGDP_initial	-3.474	-3.950	-3.305	-4.042
	(3.62)***	(3.69)***	(3.28)***	(3.71)***
mobile_pen	0.022	0.019	0.022	0.020
	(2.85)***	(2.33)**	(2.78)***	(2.38)**
gov_exp	-0.103	-0.047	-0.087	-0.033
	(1.59)	(0.82)	(1.39)	(0.60)
cap_inv	0.067	0.084		
	(1.35)	(1.45)		
life_expect	0.148	0.068	0.218	0.134
	(2.32)**	(1.38)	(3.26)***	(3.19)***
pol_terror	-0.747	-0.912	-0.895	-1.032
	(2.30)**	(3.62)***	(2.87)***	(3.95)***
trade	0.034	0.037	0.045	0.044
	(2.18)**	(2.13)**	(3.16)***	(2.92)***
years_school		0.369		0.423
		(1.74)*		(1.99)*
lag3_cap_inv			-0.033	0.008
			(0.95)	(0.28)
_cons	15.747	20.665	12.496	18.722
	(1.98)*	(2.38)**	(1.49)	(2.14)**
R^2	0.26	0.29	0.26	0.27
N	249	191	247	190

* $p<0.1$; ** $p<0.05$; *** $p<0.01$

Mobile phone penetration has a statistically significant impact in all model specifications. An increase in the mobile phone penetration of 10 phones per 100 individual is associated with 0.19-0.22 percentage points increase in average annual growth in GDP per capita, all else equal. This result is robust for small changes in the model specification.

All of the coefficients have the signs that the theory predicts them to have, two of them are presented explicitly below. The only estimations that are not statistically significant for any of the model specifications are government expenditures, capital formation and lagged capital formation. The insignificance of both forms of capital formation could be due to the difficulties of measurement as mentioned earlier.

Initial GDP per capita has a statistically significant effect on the 1% level for all model specifications, a result in line with convergence theory which states that, conditional on the other factors, a country starting with a higher level of GDP per capita they will grow slower than otherwise. These estimates predict that if you start with 10% higher GDP per capita the average growth rate of GDP per capita will be 0.35-0.40 percentage slower on average.

Political terror scale has quite a large and significant impact as well. One step up on the scale is associated with an average of 0.75-1.03 percentage points of lost growth in GDP per capita.

The R-squared is between 0.26 and 0.29 depending on the model specification. It measures how much the variation in growth in GDP per capita that is explained by the variation in the independent variables combined. This is quite a normal figure in a model such as the one tested here. As previously discussed, the aggregate economic growth of an entire country is complex and bound to be affected by many different variables, some of which fall outside this regression.

7. Analysis

The model predicts that mobile phone penetration does have an impact on growth in GDP per capita that is positive and statistically significant at the 1% level. However, in order to answer the research question, this result has to be evaluated against possible biases that the model could have in relation to reality. This analysis will focus on the factors indicating that the result could be an understatement or an overstatement of the true effects of mobile phones as well as the factors that could do either and thus bring with them a more general uncertainty.

First of all, might there be some effects that do not show up in these results? To answer this, the five channels of impact that the literature suggests can be sorted into three broad categories: the effects that have direct effect on output and should therefore have been caught by the regression, those that can be expected to affect GDP but do so with some amount of time-lag and lastly the effects that are beneficial but might not show up in the GDP per capita data. The five channels do not sort perfectly into the three categories as there is certainly some degree of overlap in each one. The economic reasoning that follows is not meant to represent, or serve as a substitute for, more detailed research into the exact nature of these five channels, but rather to shed light on one important way in which the results obtained in the regression fall short of describing reality.

Decreased information asymmetry

Constrained access to information inhibits the ability of actors to take economically rational decisions. It allows some actors to charge a premium price, or buy at a sub-market price, based on constrained competition. Lower transaction costs involved in information gathering and sharing eases some of these adverse effects by increasing competition between sellers and between buyers. One part of this effect might thus lie in a redistribution of consumer and producer surplus with an ambiguous impact on GDP. Increased market efficiency leading to higher profits and less waste, however, should have a direct positive effect on total output and be registered in the GDP-figures.

Better economic coordination for firms

The second channel identified, through which firms can better coordinate their activities, for example by allowing them to get more control over their supply chains. To the extent that this

positively impacts the profitability of existing businesses and/or attracts new entrants to the market this should have a direct effect on the aggregate GDP numbers.

Network-supporting employment

Direct employment and consumption of telecommunication services should definitely turn up in the GDP figures as they get reported. However, a substantial part of this is likely to represent consumption that would otherwise have been directed at some other sector in the economy. If consumption is redirected from imported products then GDP will be affected positively. However since a lot of trade take place between African countries this will, to some extent, cancel out in the cross country regression.

Risk mitigation through better communication

If the informal social insurance networks that exist can communicate better it should lead to lower overall risk for every individual member of the network. Reducing this risk should mean that less emergency funds needs to be held personally and could therefore be put to productive use. The economic effects here are secondary and the size of impact it might exert on aggregate GDP is hard to evaluate.

Delivery platform for M-services

This encompasses a wide array of services, the focus here are the three mentioned in the literature review. The mobile phone's role in education will pay its dividend over a longer period of time and as the M-schooling services are still quite new, productivity gains noticeable on an aggregate level are probably not to be expected in the data used for this thesis. Banking and agricultural advisory have a much more direct impact on output. If agricultural yields can be improved with the help of mobile phones this would certainly affect the results given the importance of agriculture for the overall economy. Financial inclusion through mobile banking has proved to play an enabling role in, among other things, agriculture. The M-health schemes could have some impact on the GDP per capita growth as they positively impact the general health level of the population, making people more productive. Better overall health is of course an important goal in itself and has a value that far exceeds its potential impact on economic performance.

Based on the nature of the channels of economic impact analysed above, there seems to be at least some benefits that fall outside the scope of this regression. It is thereby probable that the effect obtained in the results is an underestimation of the economic impact of mobile phones

in this regard. The underestimation is made up of the economic gains that have yet to materialise and the non-economic advantages that exist but do not show up in the regression.

It is, however, also possible that the coefficient is an overestimation of the actual impact of mobile phones. The previously discussed problems of two-way causality might be present and would result in an exaggerated coefficient. This is because the coefficient represents the ceteris paribus correlation between the two variables, made up of the causal connection in both directions but interpreted to include only one. The problem of two-way causality could be addressed in a variety of ways, all of which are beyond the scope of this thesis. However, as previously discussed, the relation between mobile phone penetration and growth should primarily lie in the absolute level of GDP rather than in the year-on-year change in GDP tested in this thesis.

The measurement problem in the mobile phone penetration variable could, as mentioned earlier, result in either an overestimation or an underestimation of the impact. As this is hard to evaluate without closer scrutiny it brings some measure of uncertainty to the results. The same is true for the problem of omitted variables, which leads to inaccuracy in the estimation, either upwards or downwards. The problem of omitted variables could be addressed by finding proxies for the effects that are mentioned in the theory, but are left out of the regression for different reasons. Some of the variables in this thesis are quite crude, for example the one measuring political stability. There are other governance-related indicators that more accurately measure the different aspects of state influence, but they exist in the data only from the mid-90s and 00s. In the future these will have accumulated enough to be included in similar regressions and could then account for the more nuanced aspects of GDP growth.

The size of impact, around 0.2 percentage points of annual per capita growth for a 10 percent rise in the mobile phone penetration, is notably smaller than the one estimated by Waverman (2005). He found 0.6 percentage points of growth dividend for the same increase in mobile phone penetration, while using a broader sample of developing countries. This difference is surprising because of the last years' rapid development of M-services in Africa in relation to other emerging countries. So with more updated data including the last few years it could be expected that the impact of mobile phones is higher today than in 2005. However, the study by Waverman only controls for those effects indicated by Barro (1991), so one explanation could be that the result from the regression in this thesis suffers from less omitted variable

bias. Another could be that the macroeconomic impact of the 2008 financial crisis has served to depress growth rates in these countries more generally, leaving less overall growth to be explained by our variables.

The coefficient, while lower than previous estimates, still conveys an economically significant result. The mobile phone penetration in Sub-Saharan Africa today stands at around three quarters on average (ITU 2015). Closing the 25 percentage point gap to reaching a regional mean of one mobile phone subscription per person thus holds the potential of raising the GDP per capita growth by 0.5 percentage points annually on average. Set against an average growth rate for all of the periods in this sample of 1.27 percent per year, this represents a substantial growth potential.

For policy purposes this result lends support to actions aimed at promoting the spread of mobile access to those who still do not have it, based on the sizable benefits that can be detected already. When taking into account that the role of the mobile phone as a service-delivery platform is still in its infancy, the case for extending networks becomes stronger still. However, the mobile phone should be seen as a part of a broader development agenda, it cannot serve as a substitute for a well-functioning transport network or good political institutions but as an important compliment.

To sum up, this thesis finds a strong, positive and statistically robust effect of mobile phone penetration on economic growth in Sub-Saharan Africa. While this result in itself contains quite a few uncertainties, it is nevertheless a clear confirmation that the widespread interest in the mobile phone is warranted and that the phenomenon is worth the time and interest of scholars in the years to come.

8. Conclusion

The aim of this thesis was to verify or nullify the hypothesis that mobile phones have a positive impact on GDP per capita growth in Sub-Saharan Africa. The hypothesis was tested empirically using a fixed effects model and panel data covering the period 1980-2013. The subsequent regression produced convincing results in support of the hypothesis. A 10 percentage point increase in mobile phone penetration corresponds to an average annual growth in GDP per capita of 0.2 percent, statistically significant at the 1% level. Significant measurement error in the mobile phone penetration variable, the potential existence of endogenity biases and the imperfect nature of GDP per capita growth as a proxy for economic progress all add some level of uncertainty. Better data for mobile phone usage, research surrounding the endogenity issue and regressions using other welfare metrics are all important fields of future work to bring more clarity to this relationship.

9. References

Aker, J. (2008). Does digital divide or provide? The impact of cell phones on grain markets in Niger. *Center for Global Development Working Paper,* 154.

Aker, J. (2009). Mobile Phones and Economic Development in Africa. Presentation at the Center for Global Development, Washington, D.C Available at: http://www.cgdev.org/doc/events/08.25.09/Cell_Phone_Survey_CGD_26aug09_Final_Public.pdf [2015-05-26]

Aker, J. & Mbiti, I. (2010). Mobile phones and economic development in Africa. *Center for Global Development Working Paper,* 211.

Aker, J. (2011). Dial "A" for agriculture: A review of information and communication technologies for agricultural extension in developing countries. *Agricultural Economics,* 42(6), pp. 631-647.

Aker, J., Klein, M. & O'Connell, S. (2014). International and Intra-National Market Segmentation and Integration in West Africa. *University of Chicago Press.*

Baliamoune-Lutz, M. (2003). An analysis of the determinants and effects of ICT diffusion in developing countries. *Information Technology for development,* 10(3), pp. 151-169.

Barro, R. (1991). Economic growth in a cross section of countries. *The Quarterly Journal of Economics,* 106(2), pp. 407-443.

Barro, R. (2003). Determinants of economic growth in a panel of countries. *Annals of economics and finance,* 4(2), pp. 231-275.

Barro, R. & Lee, J. (2013). A new data set of educational attainment in the world, 1950–2010. *Journal of development economics,* 104, pp. 184-198.

Brune, L., Giné, X., Yang, J. & Yand, D. (2014). Facilitating Savings for Agriculture: Field Experimental Evidence from Malawi. *Working paper.*

Curwen, P. & Whalley, J. (2005). Structural change in African mobile telecommunications. *Communications and Strategies,* 1(55).

Demirguc-Kunt, A., Klapper, L., Singer, D. and Van Oudheusden, P. (2015). The Global Findex Database 2014. *World Bank Policy Research Working Paper 7255.*

Donner, J. (2008). Research approaches to mobile use in the developing world: A review of the literature. *The information society,* 24(3), pp. 140-159.

Gates Fondation. (2015). 2015 Gates Annual Letter. Available at: http://www.gatesnotes.com/2015-annual-letter?lang=en&page=0 [2015-05-26]

Granot, Y., Ivorra, A. and Rubinsky, B. (2008). A new concept for medical imaging centered on cellular phone technology. *Plos one*, 3(4), e2075. DOI: 10.1371/journal.pone.0002075

Hardy, A. (1980). The role of the telephone in economic development. *Telecommunications policy*, 4(4), pp. 278-286.

Jack, W. & Suri, T. (2010). The economics of M-PESA. *MIT Sloan School of Management Working paper.*

James, J. & Versteeg, M. (2007). Mobile phones in Africa: how much do we really know?. *Social indicators research*, 84(1), pp. 117-126.

Jensen, R. (2007). The digital provide: Information (technology), market performance, and welfare in the South Indian fisheries sector. *The quarterly journal of economics*, pp. 879-924.

Mbiti, I. & Weil, D. (2011). Mobile banking: The impact of M-Pesa in Kenya. *National Bureau of Economic Research*. DOI: 10.3386/w17129

Ndulu, B., O'Connell, S., Bates, R., Collier, P. & Soludo, C. (2008). *The political economy of economic growth in Africa, 1960-2000* (Vol. 2). Cambridge University Press.

Poushter, J. et al. (2015). Cell Phones in Africa: Communication Lifeline, Texting Most Common Activity, but Mobile Money Popular in Several Countries. Available at: http://www.pewglobal.org/2015/04/15/cell-phones-in-africa-communication-lifeline/ [2015-05-26]

Röller, L. & Waverman, L. (2001). Telecommunications infrastructure and economic development: A simultaneous approach. *American economic review*, pp. 909-923.

Shanmugavelan, M. & Wariock, K. (2004). Completing the revolution: The challenge of rural telephony in Africa. *Panos Institute.* Available at: http://panos.org.uk/wp-content/files/2011/03/completing_the_revolutionaKnJmM.pdf [2015-05-26]

Sridhar, K. & Sridhar, V. (2007). Telecommunications infrastructure and economic growth: Evidence from developing countries. *Applied Econometrics and International Development, 7*(2).

Utrikespolitiska Institutet. (2015). *Landguiden.* Available at: http://www.landguiden.se [2015-05-26]

Waverman, L., Meschi, M. and Fuss, M. (2005). The impact of telecoms on economic growth in developing countries. *The Vodafone policy paper series*, 2(03), pp. 10-24.

Wooldridge, Jeffrey M. (2010). *Econometric analysis of cross section and panel data*. 2. ed., Cambridge, Massachusetts: MIT Press

Wooldridge, Jeffrey M. (2014). *Introduction to econometrics. Europe, Middle East and Africa edition*, Andover: Cengage Learning

The World Bank. (2009). Fact Sheet: The World Bank and Agriculture in Africa. Available at: http://web.worldbank.org/WBSITE/EXTERNAL/COUNTRIES/AFRICAEXT/0,,contentMDK:21935583~pagePK:146736~piPK:146830~theSitePK:258644,00.html [2015-05-26]

Data

Gibney, M., Cornett, L., Wood, R., & Haschke, P. (2013). Political Terror Scale 1976-2012. Available at: http://politicalterrorscale.org/ [2015-05-26]

Fearon, J. D. (2003). Ethnic and cultural diversity by country. *Journal of Economic Growth*, 8(2), 195-222.

International Telecommunications Union (ITU). (2015). World Telecomunication/ICT Development Report and database. Available at: http://data.worldbank.org/data-catalog/world-development-indicators [2015-05-26]

Teorell. J., Dahlberg. S., Holmberg, S., Rothstein, B., Hartmann, F. & Svensson, R. (2015). The Quality of Government Standard Dataset, version Jan15. University of Gothenburg: The Quality of Government Institute. Available at: http://www.qog.pol.gu.se [2015-05-26]

The World Bank. (2015). World Development Indicators database (WDI). Washington, DC: The World Bank. Available at: http://data.worldbank.org/data-catalog/world-development-indicators [2015-05-26]

The World Bank. (2015). Education statistics. Washington, DC: The World Bank. Available at: http://data.worldbank.org/data-catalog/ed-stats [2015-05-26]

10. Appendices

10.1 Appendix I – Variable definitions and sources

Variable	Description	Source
country	Country, 47 countries in Sub-Saharan Africa	
time	Time, 1985, 1990, 1995, 2000, 2005, 2010, 2013	
gdp_growth	Real GDP per capita growth (annual %)	The World Bank, World Development Indicators database (WDI)
logGDP_initial	Logarithmic form of GDP per capita (constant 2005 USD)	The World Bank, World Development Indicators database (WDI)
mobile_pen	Mobile cellular Penetration (per 100 people)	International Telecommunications Union, World Telecomunication/ICT Development Report and database.
gov_exp	General government final consumption expenditure (% of GDP)	The World Bank, World Development Indicators database (WDI)
cap_inv	Gross fixed capital formation (% of GDP)	The World Bank, World Development Indicators database (WDI)
years_school	Average years of total schooling, Age 15+. total	The World Bank, Education statistics
life_expect	Life expectancy at birth, total (years)	The World Bank, World Development Indicators database (WDI)
res_rich	= 1 if resource rich, 0 otherwise	Calculation from *The political economy of economic growth in Africa, 1960-2000*
coastal	= 1 if coastal, 0 otherwise	Calculation from *The political economy of economic growth in Africa, 1960-2000*
pol_terror	Average political terror score	The Quality of Government Standard Dataset, original from Gibney, M. et al. (2013)
ethnic_frac	Ethnic fractionalization	The Quality of Government Standard Dataset, original from Fearon, J. (2003).
trade	Merchandise trade (% of GDP)	The World Bank, World Development Indicators database (WDI)
lag3_cap_inv	Lag 3 years average capital investment	The World Bank, World Development Indicators database (WDI)

10.2 Appendix II – Random effect model

Output from the estimation with the random effect model

	(1)	(2)	(3)	(4)
logGDP_initial	-0.859	-1.292	-1.002	-1.361
	(3.17)***	(3.92)***	(3.67)***	(4.11)***
mobile_pen	0.015	0.011	0.017	0.013
	(2.21)**	(1.34)	(2.62)***	(1.67)*
gov_exp	-0.090	-0.082	-0.072	-0.056
	(2.51)**	(1.75)*	(1.91)*	(1.37)
cap_inv	0.058	0.060		
	(1.43)	(1.09)		
life_expect	0.109	0.085	0.152	0.121
	(3.03)***	(2.80)***	(4.22)***	(4.65)***
res_rich	0.914	1.051	1.190	1.419
	(1.47)	(1.89)*	(1.79)*	(2.71)***
coastal	-0.133	0.778	-0.055	0.780
	(0.19)	(1.22)	(0.08)	(1.23)
pol_terror	-0.237	-0.512	-0.376	-0.567
	(1.05)	(2.20)**	(1.68)*	(2.37)**
ethnic_frac	-1.612	-2.124	-1.446	-1.894
	(1.58)	(2.12)**	(1.33)	(1.93)*
trade	0.034	0.026	0.040	0.032
	(3.23)***	(2.42)**	(4.25)***	(3.03)***
years_school		0.408		0.428
		(2.38)**		(2.45)**
lag3_cap_inv			-0.026	-0.013
			(0.97)	(0.47)
_cons	0.413	3.774	0.194	2.814
	(0.21)	(1.77)*	(0.10)	(1.27)
N	249	191	247	190

* $p<0.1$; ** $p<0.05$; *** $p<0.01$